PB81-191991

Prediction of Agricultural Worker Safety Reentry Times for Organophosphate Insecticides

Agricultural Research and Education Center
Lake Alfred, FL

Prepared for

Health Effects Research Lab.
Research Triangle Park, NC

1980

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/J-80-262	2. Journal Article	3. PB81-191991
4. TITLE AND SUBTITLE: Prediction of agricultural worker safety reentry times for organophosphate insecticides		5. April 1981 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Herbert N. Nigg		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: University of Florida Institute of Food and Agricultural Sciences P.O. Box 1088, Lake Alfred, Florida 33850		10. PROGRAM ELEMENT NO. CCAE1A 11. CONTRACT/GRANT NO. Grant R-806474-01
12. SPONSORING AGENCY NAME AND ADDRESS: Office of Research and Development RTP, 27711 Health Effects Research Lab US Environmental Protection Agency		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA-600/11

15. SUPPLEMENTARY NOTES

Published In: American Industrial Hygiene Association Journal 41: 340-345, 1980

16. ABSTRACT

Concepts and current methods of determining worker safety reentry times are reviewed. Comparison of human monitoring studies, factors in a worker reentry episode and exposure estimation methods illustrate the advantages of estimation methods. Research needs for worker reentry times are discussed. A systematic view of the worker reentry situation is suggested.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

PRODUCT OF:
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	CLASSIFIED	
	20. SECURITY CLASS (This page) CLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

EPA-600/J-80-262
Journal Article

Concepts and current methods of determining worker safety reentry times are reviewed. Comparison of human monitoring studies, factors in a worker reentry episode and exposure estimation methods illustrate the advantages of estimation methods. Research needs for worker reentry times are discussed. A systematic view of the worker reentry situation is suggested.

Prediction of agricultural worker safety reentry times for organophosphate insecticides

HERBERT N. NIGG
University of Florida, Institute of Food and Agricultural Sciences, Agricultural Research and Education Center, P.O. Box 1088, Lake Alfred, Florida 33850

introduction

The exposure of agricultural labor to chemicals in the workplace has received increasing regulatory and scientific attention. One group of exposed workers is the harvester or hand laborer who comes in contact with pesticide-treated foliage and pesticide-laden dust from the soil surface. The organophosphate intoxication of fieldworkers was the subject of a task force report which documented the acute pesticide intoxication of fieldworkers over a period of 20 years in the Western United States.[1] The California worker reentry situation was reviewed in 1977.[2]

To reduce the exposure of fieldworkers to residues of the organophosphate insecticides, the U.S. Environmental Protection Agency (EPA) has set reentry periods for fieldworkers for 14 organophosphate pesticides. These national standards require that agricultural laborers not enter a treated field for 24 to 48 hours after an organophosphate application, the time dependent upon the specific organophosphate. For pesticides with no reentry time, workers must wait until the spray has dried or the dust has settled. The California Department of Food and Agriculture has set more stringent regulations for California agriculture. California's reentry regulations include more than 20 organophosphate insecticides and reentry times vary from 1 day for malathion to 45 days for high rates of parathion.[1]

Worker safety reentry times should not be confused with "Preharvest intervals." Preharvest intervals are designed to protect the general American public from *ingestion* of excessive pesticide residues in foodstuffs. These intervals are times a grower must wait after a pesticide application before harvesting a commodity. Worker reentry times are designed to protect fieldworkers from dermal, respiratory and oral exposure to *surface* residues on foliage and soil surfaces and in air. Preharvest intervals do not necessarily protect fieldworkers and should not be used for their protection.

Monitoring of residue levels would also protect fieldworkers from hazardous pesticide residues.[2] Field monitoring through a rapid color reaction would allow determination in about 20 minutes of organophosphate levels on leaf and soil surfaces. This technology has been developed into a field kit and should fieldworker illnesses in the Western United States continue in spite of reentry regulations, monitoring may become a necessity.[2]

Estimation of worker reentry times using the known toxicity and the estimated environmental behavior of the chemical after an agricultural application[5-8] is also an attractive approach to the protection of fieldworkers from pesticide residues.

The current EPA reentry times, the California reentry times and the estimation method assume that there is decreasing hazard to a fieldworker with increasing time after application. However, hazard to the fieldworker can increase or only slowly decrease under some environmental conditions.[2] Thus, in presence of environmental conditions favorable to persistent residues, conversion to an oxon metabolite with a toxicity of 10 to 100X that of the parent pesticide may present a more hazardous situation with increasing time after application.[2,9]

The purpose of this paper was to acquaint the industrial hygiene community with worker safety reentry research and to identify needs for future development in this area.

human exposure studies

It was recognized 30 years ago that parathion-laden dust in a citrus grove could be hazardous to citrus workers[3] and several studies have focused on the exposure of harvesters through pesticide-laden dust.[2] The primary exposure of fieldworkers is apparently dermal with smaller respiratory and oral components.[2] Fieldworkers "dislodge" pesticide-laden particulate matter from leaf, fruit and soil surfaces. These pesticide-laden particulates settle on the worker, penetrate the clothing and are breathed. The specific combination of dermal, oral or respiratory exposure depends on particulate size.[2,4]

There is criticism of human studies on ethical grounds and animal models have been suggested to circumvent human studies.[10,11] Human exposure studies fall into two categories: the monitoring of human subjects at various time intervals after a pesticide application to determine safe

Copyright 1980, American Industrial Hygiene Association

NTIS is authorized to reproduce and sell this report. Permission for further reproduction must be obtained from the copyright proprietor.

pp.340-345

reentry conditions and the monitoring of human subjects at the estimated legal reentry time. Early studies of both types have been reviewed.[1] More recently, Spear *et al.*[12] correlated dermal and respiratory exposure of California orange pickers with parathion and paraoxon residues with red-blood cell cholinesterase depression. They concluded that the primary route of exposure was dermal and that paraoxon was the principal intoxicant. Further, based on analyses of exposure pads on various anatomic regions of the workers, the source of exposure was leaf residues. In three separate and subsequent California worker reentry incidents, leaf residues of paraoxon residues were implicated as the intoxicant.[13] High paraoxon residues were speculated to be the result of *"a transient and unusual set of environmental conditions."* A reentry study was conducted by Knaak *et al.*[14] for phosalone and its oxon metabolite in California citrus. Based on exposure pad analyses, exposures were highest on the thigh, back and shoulder and lowest on the chest. Plasma cholinesterase activities of control and exposed subjects were different in both the 14-day and 21-day post application exposures, probably due to the differences in residue dissipation rates between experiments. Knaak *et al.*[15] also investigated an illness episode among grape harvesters involving dialifor and phosalone. Dialifor residue dissipation appeared to be quite variable and monitoring of dialifor residues before field reentry was suggested to protect harvesters. In a follow-up study, Winterlin *et al.*[16] determined dialifor and dialifor oxon dislodgeable residue levels present in the incident vineyards. Unusual dialifor oxon residues were found. Knaak *et al.*[17] compared cholinesterase activity in several hundred field and non-field workers in California to determine if excessive organophosphate exposure was occurring. Results were inconclusive. Kraus *et al.*[18] studied California peach thinners exposed to azinphosmethyl residues 14 days after application. Whole blood cholinesterase values, urinary alkylphosphates and azinphosmethyl residues were determined. These thinners were mistakenly exposed to 14-day residues plus 12- to 18-hour residues of azinphosmethyl due to a misunderstanding between a rancher and his foreman. Urinary metabolite determinations indicated minimal absorption of this compound and cholinesterase value variations appeared to be random. It should be noted that azinphosmethyl oxon residues were only 0.5% or less of the parent azinphosmethyl residues during this reentry experiment. Extensive worker monitoring studies were also conducted by the Kilgore group[19] for California peach thinners, lettuce harvesters and artichoke harvesters. Significant decline in cholinesterase values for peach thinners exposed to azinphosmethyl were not observed. Exposure of artichoke harvesters to parathion, methyl parathion and their oxygen analogs resulted in no cholinesterase depression. Results were similar for lettuce harvesters exposed to mevinphos and methomyl (a carbamate insecticide) in the Imperial and Salinas valleys. Levels of mevinphos oxon were low during these studies and disappearance of parent compounds was rapid. These studies illustrate a persistent difficulty in determining worker safety reentry times. Under normal conditions, disappearance of the parent compound from leaf and soil surfaces is rapid and oxon metabolites are low. Where fieldworkers have become acutely ill, organophosphate residues were persistent and oxon metabolite residues were usually above the parent residue level.

estimation methods

Serat and co-workers originally suggested the worker reentry time could be estimated without exposing human subjects.[5–8] Serat's initial experiment utilized citrus harvesters monitored for acetylcholinesterase depression with simultaneous determination for foliar residues.[5] The assumption was made that pesticide loss and cholinesterase depression were first-order processes. Cholinesterase depression was correlated with the level of residue exposure. This correlation allowed the estimation exposure to residue levels which would depress cholinesterase 30%. In a second study, Serat and Bailey[7] introduced the toxicologic potential concept and defined the toxicologic potential as the ratio between the pesticide residue level on foliage and the dermal LD_{50} value. This is an important adjustment for different toxicities, and since all values are divided by a constant (the dermal LD_{50}), kinetics are not complicated in the process. Serat *et al.*[8] also proposed that enough data are available to estimate worker reentry intervals without the exposure and monitoring of human subjects. Serat[6] extended the estimation of organophosphate reentry times to carbamate insecticides.

soil surface residues

Soil surface residues are important to the harvester exposure process. These residues provide a source of residue for direct worker exposure and for transfer through wind and agricultural operations to foliage and fruit surfaces. Coupled with the catalytic conversion by particulate matter of the parent compound to an oxon metabolite, the behavior of soil-borne residues is integral to predicting a worker safety reentry time.

Several authors have proposed pesticide-laden soil dust and wettable powder formulations as important factors in a worker reentry incident.[2] Adams *et al.*[20] determined that conversion of parathion to paraoxon was influenced by soil type. Conversion to paraoxon was highest with Pike's Peak clay, a wettable powder formulation. This material is no longer used for wettable powders. Visalia silt loam collected from a worker illness episode grove (1974) also contained high levels of paraoxon. Subsequent studies of soil type vs. paraoxon dissipation on citrus foliage indicated that larger surface area soils appeared to reduce paraoxon dissipation. Organic matter and clay content were apparently not correlated with dissipation. It should be noted that high clay content soils will have a higher surface area by definition. Iwata *et al.*[21] showed in the laboratory that in some soils under dry conditions parathion and phenothoate are quite persistent. Field studies with phenothoate also showed persistence in dry soil.[22] In an important pioneering study, Spencer *et al.*[23] showed that parathion is rapidly converted

to paraoxon at the soil *surface*, is very persistent under dry conditions and disappears rapidly with wetting. Smith *et al.*[24] studied methadathion behavior on thin layers of dry soil. The oxygen analog was highest in soil exposed to sunlight and 500 ppb of ozone, intermediate for soil exposed to sunlight and lowest in soil stored in the dark. In some soils, the oxon metabolite reached levels well above the parent compound. Spear *et al.*[25] showed that parathion is converted to paraoxon on foliage in the presence of dust and this conversion is greatly accelerated by dust and 300 ppb ozone. Little conversion to paraoxon occurred in the presence of ozone alone. These data have led to studies of protective clothing for harvesters[26] and pesticide deposition on citrus grove soil.[26,27] Specific recommendations have been made for the collection of soil residues within the work environment in relation to worker exposure.[28]

foliage and fruit pesticide residues

Several studies have implicated surface pesticide residues sorbed to particulates on foliage and fruit as the source of harvester exposure.[2] These particulates are dislodged during harvesting operations, settle on the harvester, and the sorbed pesticide penetrates dermally. Since the dose the harvester receives is integral to the intoxication process, the accurate estimation of surface residues after application is central to the estimation of a worker safety reentry time.[9,25,29-32]

The estimation of pesticide disappearance has traditionally depended on first-order kinetics and in some cases as two first-order kinetic processes.[2] This model cannot apparently be used to describe surface residue dissipation under 'the unusual environmental conditions' which occur prior to a worker reentry episode or to describe the variation in residue disappearance between geographical regions.[2,30] Pesticide dissipation may, in fact, be represented more accurately by other kinetic models.[30] Regardless of the model used, when time is used as a basis for estimation, inaccuracies will occur because of variation in residue dissipation due to changing environmental conditions. To estimate human exposure, several authors have strongly advocated modeling of residue behavior as related to weather.[9,29-36]

Consequently, the relationship of surface residue behavior to changing environmental conditions is central to accurately calculating residue levels.

Popendorf and Leffingwell correlated conversion of parathion to paraoxon with ozone level and dew point, but concede that the agent responsible for this conversion was probably not monitored.[34] Nigg *et al.*[31,32] obtained good correlations of ethion, parathion and carbophenothion residue behavior with rainfall, dew, temperature and time. These correlations were also made for California data. Weather correlations explained 85% or more of the variation in residue behavior. The use of time was only half as accurate. Spear *et al.*[35] monitored 32 citrus groves in central California for parathion and paraoxon residues and data were fitted to a first-order time model. It was concluded that the effect of factors important to the decay process, i.e., weather, should be determined in the establishment of worker safety reentry times. A similar conclusion was reached in a study of ethion and zolone residue in California.[37] Adams *et al.* determined that soil dust on foliage is a factor in surface residue dissipation.[38]

regulation

Modeling of pesticide behavior to set a worker safety reentry time is a very attractive approach. It allows the introduction of science into the regulatory process. This is apparently hard for regulatory agencies to accept. Worker reentry regulations to date have been arbitrary, the data available have been used poorly, and regulatory personnel appear to care more about flexing federal power than about soundly-based decisions. For example, worker safety reentry times were recently set for 10 and 11-year-old minors in hand harvesting of short season crops.[39] The Department of Labor depended on reports from Clement Associates, Inc. to set these regulations. The original report of 7 August 1978 contained the following qualifying statement: "*It was not possible, within the short time available for this study, to perform thorough literature searches on such topics as pesticide toxicity, the pharmacological differences between adults and children, and past attempts at determining safe reentry intervals. We decided therefore to base our conclusions on pesticide toxicity data provided for the most part in secondary sources and to build on the existing standards for adults without critically evaluating the scientific adequacy of either. We did not review data submitted by manufacturers and formulators. Assuming the current standards are reasonable for adults, we have suggested interim standards that may be defensible as being reasonable for 10- and 11-year-olds.*"

The final preliminary report of 20 April 1979 contained the following statement "*Accordingly, although we have reviewed data on metabolism, residue dynamics, and toxicity for each pesticide, we have not attempted to use these data in a formal way to set standards. For the reasons given above, we conclude that basing standards on these factors systematically would not be possible without the generation of extensive new data. In the severely limited time available for this study, we have chosen instead to use an indirect method for developing reentry intervals for 10- and 11-year-old children.*"

It is not the writer's intention to criticize Clement Associates, Inc. Based on the second statement, they operated under substantial political pressure to produce in a short time. However, both statements are examples of the lack of basis for worker safety reentry regulations. In addition, the U.S. Department of Labor and the U. S. Environmental Protection Agency both regulate worker reentry times. These two agencies do not have the money or personnel to oversee every harvesting operation in the U.S.

modeling concepts

The modeling approach would, to a large extent, circumvent the necessity for regulatory oversight by accurately estimating when a pesticide-treated field is safe for human

reentry. To do this, models of pesticide behavior need several qualities. First, they must be accurate. This accuracy may mean dependence on kinetics other than first-order and certainly means dependence on the environmental factors affecting residue behavior. Models currently used for residue behavior are about 50% accurate if based on days after application and about 85% accurate if based on the weather.[28-31] How accurate must a model be to set a worker safety reentry time? It would be preferable if a model of residue behavior could be applied to the entire U.S. There are obvious differences in residue behavior comparing hot and dry California to hot and wet Florida. The model should account for these differences. How different in real terms is residue behavior in various geographical regions of the U.S.?

Models should be field tested. This is a sore point with those regulatory agencies which frequently use old data to set regulations. However, testing of the *"final"* model of residue behavior in several geographical regions would indicate the accuracy of the model in actual use.

Models should be simple to use. It is one thing to generate an accurate model of parathion behavior based on a diffusion constant or hydrolysis rate using elegant mathematics, but an extension agent or a farmer needs a simple and utilitarian tool to use in his business.

With particular regard to organophosphate pesticides, the model should account for the production and dissipation of the toxic oxon metabolites. The model should also include the environmental sensitivity of different organophosphates. That is, it should include the ease of conversion to an oxon metabolite.[9] This sensitivity should be related to soil type and geographical region of the United States.

needed research

Several areas of research need continuing attention. The exposure process for workers is a critical area. Little is known of the relationship between soil type, foliar particulates and subsequent fieldworker exposure. This relationship must be known to predict the dosage a fieldworker obtains in the workplace and whether that exposure is dermal, oral or respiratory.

The environmental factors involved in pesticide residues dissipation must be identified and this knowledge incorporated into regulatory decisions. What are the *"unusual"* weather conditions which lead to a fieldworker episode? Do these conditions exist in any area of the country other than California? How many different chemicals are affected by the same factors that affect the organophosphates?

An in-depth epidemiological study of fieldworkers should be conducted. This is a difficult task. But, are workers actually in worse health due to exposure to chemicals? Can exposure to chemicals be identified as a health risk in the case of fieldworkers? Or are there so many health problems that are endemic to fieldworker populations that chemical exposure is not relatively important?

An understanding of the variability of exposure situations would be helpful. Are workers exposed differently in tobacco than in citrus, apples, potatoes or strawberries? Do differences warrant different regulations?

How should exposure be measured? Although it is agreed that urinary metabolites should be measured in monitoring studies, urinary metabolite methods for most of the agricultural chemicals are under development. Should exposure of farmworkers be measured with exposure pads, urinary metabolites and biochemical indicators such as the measurement of acetylcholinesterase? Once exposure is measured, how does this relate to a health effect? What level of exposure to pesticides is safe for fieldworkers? Public health professionals could proceed now in determining levels of surface organophosphate pesticides safe for worker exposure.

How have pest management practices affected worker reentry episodes? For instance, parathion may be applied at more than 8 lbs/acre in a single application to California citrus, but at only 2 lbs/acre to Florida citrus. Chemicals may also be applied at different times of the year depending upon the pest in question. The pest population may thus control the proximity to harvest of a pesticide application in different hand-harvested crops and in different geographical areas. It is entirely conceivable that American agriculture has unknowingly played a statistical game with the exposure of fieldworkers to pesticides.

conclusion

Although areas of worker exposure research need attention, data are already available for regulatory consideration. The role of particulate matter and soil type in fieldworker illnesses is documented. Conversion of parent organophosphates to oxon metabolites as related to worker reentry episodes is documented. The role of weather conditions in residue persistence is documented. Weather models of residue persistence are available and can be improved. Should field monitoring become necessary the technology is available. Techniques for determining pesticide residue levels related to fieldworker exposure are developed and in common use. Yet a consistently disjointed regulatory approach to worker safety reentry times persists. A unified, encompassing, systematic approach would solve any current and future problems of harvester exposure to chemicals. Current technology can provide the data, and mathematical models can provide the framework for the systematic approach to work safety reentry times.

acknowledgement

Supported by Environmental Protection Agency Grant no. R80647401 and by special funds from the Center for Environmental Programs, University of Florida, 2014 McCarty Hall, Gainesville, FL 32611. Florida Agricultural Experiment Stations Journal Series No. 1865.

references

1. *Occupational Exposure to Pesticides.* Report to the Federal Working Group on Pest Management from the Task Group on

Occupational Exposure to Pesticides. [T. H. Milby, Chairman] 155 pages (1974).

2. **Gunther, F. A., Y. Iwata, G. E. Carman and C. A. Smith:** The Citrus Reentry Problem: Research on Its Causes and Effects, and Approaches to Its Minimization. *Residue Rev. 67*:1 (1977).
3. **Carman, G. E., F. A. Gunther, R. C. Blinn and R. D. Garmus:** The Physical Fate of Parathion Applied to Citrus. *J. Econ. Entomol. 45*:767 (1952).
4. **Nigg, H. N.:** Comparison of Pesticide and Particulate Recoveries With the Vacuum and Dislodgeable Surface Pesticide Residue Techniques. *Arch. Environ. Contam. Toxicol. 8*:369 (1979).
5. **Serat, W. F.:** Calculation of a Safe Reentry Time into an Orchard Treated with a Pesticide Chemical Which Produces a Measurable Physiological Response. *Arch. Environ. Contam. Toxicol. 1*:170 (1973).
6. **Serat, W. F.:** Estimating a Worker Entry Interval for the Carbamate Pesticide Furadan 4E Insecticide. *Arch. Environ. Contam. Toxicol. 7*:1 (1978).
7. **Serat, W. F. and J. B. Bailey:** Estimating the Relative Toxicological Potential of Each Pesticide in a Mixture of Residues on Foliage. *Bull. Environ. Contam. Toxicol. 12*:682 (1974).
8. **Serat, W. F., D. C. Mengle, H. P. Anderson and E. Kahn:** On the Estimation of Worker Entry Intervals into Pesticide Treated Fields With and Without the Exposure of Human Subjects. *Bull. Environ. Contam. Toxicol. 13*:506 (1975).
9. **Spear, R. C.:** Organophosphate Residue Poisoning Among Agricultural Fieldworkers in the Western United States: Towards a Strategy for a Long-Term Solution: *Center for Resource and Environmental Studies Report AS/R18, Australian National Univ.* 35 pp. (1978).
10. **Guthrie, F. E., J. J. Domanski, A. R. Main, D. G. Sanders and R. R. Monroe:** Use of Mice for Initial Approximation of Reentry Intervals into Pesticide-Treated Fields. *Arch. Environ. Contam. Toxicol. 2*:233 (1974).
11. **Skinner, C. and W. Kilgore:** Development of an Animal Model for Prediction of Agricultural Field Reentry Hazard. *Toxicol. Appl. Pharmacol. 45*:234 (1978).
12. **Spear, R. C., W. J. Popendorf, J. T. Leffingwell, T. H. Milby, J. E. Davies and W. F. Spencer:** Fieldworker's Response to Weathered Residues of Parathion. *J. Occup. Med. 19*:406 (1977).
13. **Spear, R. C., W. J. Popendorf, W. F. Spencer and T. H. Milby:** Worker Poisonings Due to Paraoxon Residues. *J. Occup. Med. 19*:411 (1977).
14. **Knaak, J. B., K. T. Maddy, M. A. Gallo, D. T. Lillie, E. M. Craine and W. F. Serat:** Worker Reentry Study Involving Phosalone Application to Citrus Groves. *Toxicol. Appl. Pharmacol. 46*:363 (1978).
15. **Knaak, J. B., S. A. Peoples, T. J. Jackson, A. S. Fredrickson, R. Enos, K. T. Maddy, J. B. Bailey, M. E. Dusch, F. A. Gunther and W. L. Winterlin:** Reentry Problems Involving the Use of Dialifor on Grapes in the San Joaquin Valley of California. *Arch. Environ. Contam. Toxicol. 7*:465 (1978).
16. **Winterlin, W., W. Kilgore, C. Mourer, R. Mull, G. Walker, J. Knaak and K. Maddy:** Dislodgeable Residues of Dialifor and Phosalone and Their Oxygen Analogs Following a Reported Worker-Injury Incident in the San Joaquin Valley, California. *Bull. Environ. Contam. Toxicol. 20*:255 (1978).
17. **Knaak, J. B., K. T. Maddy, T. Jackson, A. S. Fredrickson, S. A. Peoples and R. Love:** Cholinesterase Activity in Blood Samples Collected from Field Workers and Nonfield Workers in California. *Toxicol. Appl. Pharmacol. 45*:755 (1978).
18. **Kraus, J. F., D. M. Richards, N. O. Borhani, R. Mull, W. W. Kilgore and W. Winterlin:** Physiological Response to Organophosphate Residues in Field Workers. *Arch. Environ. Contam. Toxicol. 5*:471 (1977).
19. *Human Physiological Effects of Organophosphorus Pesticides in a Normal Agricultural Field Labor Population. A Preliminary Report.* II. Scientific Aspects [ed., W.W. Kilgore] Food Protection and Toxicology Center, U. of CA, Davis, 59 pp. (1977).
20. **Adams, J. D., Y. Iwata and F. A. Gunther:** Worker Environment Research. IV. The Effect of Dust Derived from Several Soil Types on the Dissipation of Parathion and Paraoxon Dislodgeable Residues from Citrus Foliage. *Bull. Environ. Contam. Toxicol. 15*:547 (1976).
21. **Iwata, Y., M. E. Dusch, W. E. Westlake and F. A. Gunther:** Behavior of Five Organophosphorous Pesticides in Dust Derived from Several Soil Types. *Bull. Environ. Contam. Toxicol. 14*:49 (1975).
22. **Iwata, Y., W. E. Westlake, J. H. Barkley, G. E. Carman and F. A. Gunther:** Behavior of Penthoate (Cidial) Deposits on and in Grapefruits, Lemons and Lemon Leaves, Oranges and Orange Leaves, and in the Soil Beneath Orange Trees. *J. Agric. Food Chem. 25*:362 (1977).
23. **Spencer, W. F., M. M. Cliath, K. R. Davis, R. C. Spear and W. J. Popendorf:** Persistence of Parathion and Its Oxidation to Paraoxon on the Soil Surface as Related to Worker Reentry into Treated Crops. *Bull. Environ. Contam. Toxicol. 14*:265 (1975).
24. **Smith, C. A., Y. Iwata and F. A. Gunther:** Conversion and Disappearance of Methidathion on Thin Layers of Dry Soil. *J. Agric. Food Chem. 26*:960 (1978).
25. **Spear, R. C., Y. S. Lee, J. T. Leffingwell and D. Jenkins:** Conversion of Parathion to Paraoxon in Foliar Residues: Effects of Dust Level and Ozone Concentration. *J. Agric. Food Chem. 26*:434 (1978).
26. **Kawar, N. S., F. A. Gunther, W. F. Serat and Y. Iwata:** Penetration of Soil Dust Through Woven and Nonwoven Fabrics. *J. Environ. Sci. Hlth. B13*:401 (1978).
27. **Carman, G. E., Y. Iwata and F. A. Gunther:** Pesticide Deposition on Citrus Orchard Soil Resulting from Spray Drift and Runoff. *Bull. Environ. Contam. Toxicol. 18*:706 (1977).
28. **Spencer, W. F., Y. Iwata, W. W. Kilgore and J. B. Knaak:** Worker Reentry into Pesticide-Treated Crops. II. Procedures for the Determination of Pesticide Residues on the Soil Surface. *Bull. Environ. Contam. Toxicol. 18*:656 (1977).
29. **Nigg, H. N. and J. C. Allen:** A Comparison of Time and Time-Weather Models for Predicting Parathion Disappearance Under California Conditions. *Environ. Sci. Technol. 13*:231 (1979).
30. **Nigg, H. N., J. C. Allen and R. F. Brooks:** Weather and Pesticide Residues. *Proc. Int. Soc. Citriculture 2*:437 (1977).
31. **Nigg, H. N., J. C. Allen, R. F. Brooks, G. J. Edwards, N. P. Thompson, R. W. King and A. H. Blagg:** Dislodgeable Residues of Ethion in Florida Citrus and Relationships to Weather Variables. *Arch. Environ. Contam. Toxicol. 6*:257 (1977).
32. **Nigg, H. N., J. C. Allen, N. P. Thompson, G. J. Edwards and R. F. Brooks:** Dislodgeable Residues of Parathion and Carbophenothion in Florida Citrus: A Weather Model. *Bull. Environ. Contam. Toxicol. 19*:578 (1978).
33. **Freed, V. H., C. T. Chiou and R. Hague:** Chemodynamics: Transport and Behavior of Chemicals in the Environment — A Problem in Environmental Health. *Environ. Health Perspec. 20*:55 (1977).
34. **Popendorf, W. J. and J. T. Leffingwell:** Natural Variations in the Decay and Oxidation of Parathion Foliar Residues. *J. Agric. Food Chem. 26*:437 (1978).

35. **Spear, R. C., W. J. Popendorf, J. T. Leffingwell and D. Jenkins:** Parathion Residues on Citrus Foliage: Decay and Composition as Related to Worker Hazard. *J. Agric. Food Chem. 23*:808 (1975).

36. *Environmental Dynamics of Pesticides.* [ed. V. H. Freed and R. Hague] Plenum, NY 387 pp. (1975).

37. **Leffingwell, J. T., R. C. Spear and D. Jenkins:** The Persistence of Ethion and Zolone Residues on Grape Foliage in the Central Valley of California. *Arch. Environ. Contam. Toxicol. 3*:40 (1975).

38. **Adams, J. D., Y. Iwata and F. A. Gunther:** Worker Environment Research V. Effect of Soil Dusts on Dissipation of Paraoxon Dislodgeable Residues on Citrus Foliage. *Bull. Environ. Contam. Toxicol. 18*:445 (1977).

39. **Department of Labor, Wage and Hour Division:** *Fed. Reg.* 24058-24060 (24 April 1979).